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Export of California Strawberries To Europe Via Jet Airfreighter—1966-1967

Factors Affecting Market Quality on Arrival

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Export of California Strawberries To Europe Via Jet Airfreighter—1966–1967

Factors Affecting Market Quality on Arrival

By *John M. Harvey, investigations leader,* and *C. Max Harris* and *H. Melvin Couey, physiologists, Market Quality Research Division, Agricultural Research Service*

SUMMARY

Export shipments of California fresh strawberries averaged slightly over 28 hours for delivery at European airports. About 14 hours were spent on the plane, about 12 hours in airports, and less than 3 hours in the truck going to the airport.

Ambient temperatures were near 60° F. during most of the time on the plane and at all airports except the origin airport, where the temperature averaged 67°. It averaged 44° in the truck going to the airport.

Well-precooled fruit had an average temperature at destination of 43° F. in the middle layers and 57° in the top layers when shipped in fiberboard pallet covers.

Temperatures of fruit shipped in a nitrogen refrigerated container were most affected by the amount of precooling before shipment. The container tended to maintain initial temperatures, but did not cool the fruit below its initial temperature. Temperatures varied considerably within the container.

In the 1967 tests, atmospheres around berries shipped in sealed pallet covers with dry ice had 10.5 to 21 percent carbon dioxide (CO_2) and 13 to 15 percent oxygen (O_2) at destination. Negligible amounts of CO_2 were in the nitrogen refrigerated container at destination and O_2 was as low as 0.5 percent in one shipment.

Strawberries shipped in high CO_2 atmospheres had less decay than when shipped in normal atmospheres. Berries softened less in high CO_2 atmospheres than in low O_2 or normal atmospheres.

BACKGROUND

California fresh strawberries shipped to Europe in 1966 amounted to 37 carlot equivalents or 666,000 pounds; in 1965, 45 carlots or 817,200 pounds were shipped. In the first 6 months of 1967, 100 carlots or 1,812,857 pounds of fresh strawberries were shipped to Europe, portending a record volume for the full year (*1, 2, 8*).[1]

The volume of shipments in the spring is highest in March and April; in the fall the volume peaks in October. Frankfurt, Germany, far exceeds other European markets in volume received and is followed by Stockholm, London, Zurich, Helsinki, and several other European cities.

Export shipments require a greater number of transfers, more handling, and a longer time in transit than domestic shipments (*6, 7*). The effects of pallet covers, refrigerated containers, transit temperatures, modified atmospheres, and other factors on strawberry shipments needed to be determined to develop improved methods of maintaining the quality of exported fruit.

[1] Italic numbers in parentheses refer to Literature Cited, p. 10.

METHODS

Export tests were made in the spring and fall of 1966 and in the spring of 1967, as shown in table 1. They originated in Santa Maria, Oxnard (Saticoy), or Watsonville, Calif., where strawberries were received from nearby fields for precooling and palletizing.

Test flats of berries were selected at the receiving dock to insure that all fruit used to test each variable was as uniform as possible in respect to origin, quality, size, and maturity. These flats were placed in the top and middle layers of each pallet load of fruit tested. The standard pallet load contains 72 flats of berries, although sometimes it has 60 or 84 flats.

TABLE 1.—*Air export tests with California strawberries, 1966–67*

Date of test	Carrier and flight No.[1]	Shipping origin in California [2]	Stops or transfers en route	Destination	Accompanied
1966					
May 3	TWA 580	Santa Maria	San Francisco, Chicago, New York.	Frankfurt	Yes.
Oct. 18	UAL 972, SW 300	Watsonville	New York, Stuttgart.	do	Yes.
Oct. 21	UAL 972, SW 300	do	New York, Paris.	do	No.
1967					
May 5	TWA 576, TWA 570	do	Los Angeles, Indianapolis, New York, Madrid, Frankfurt.	Zurich	Yes.
May 9	TWA 580	Oxnard	San Francisco, Chicago, New York.	Frankfurt	No.
May 13	TWA 580	do	San Francisco, Chicago, Dayton, New York.	London	No.

[1] TWA = Trans World Airlines, UAL = United Airlines, SW = Seaboard World Airlines. These are regularly scheduled cargo flights.

[2] Flights for Santa Maria and Oxnard shipments originated at Los Angeles International Airport; flights for Watsonville shipments originated at San Francisco International Airport.

Precooling

All fruit for export was precooled. Most test lots were held in the precooling room overnight and were shipped the following morning, but in a few tests, berries were cooled rapidly in a "forced air" cooler (*5*) and were shipped on the day of harvest.

Pallet Covers

Pallet covers were placed over the berries after they had been precooled and just before they were shipped from the precooling plant. Three types of pallet covers usually were compared in transit (fig. 1): (1) A regular cover, in which the top and sides of the load of berries were enclosed by a fiberboard sleeve and cap; (2) a pallet covered by a sleeve and cap as in (1), but with the additional protection of a 4-mil polyethylene liner placed between the berries and the sleeve and stapled to the floor of the wooden pallet, which also was covered by fiberboard and polyethylene; and (3) a pallet covered by a sleeve and cap as in (1), but with the fiberboard coated with a mixture of wax and polyethylene and all seams taped tightly closed. The coated pallet also had a floor covering that was taped to the sleeve. Pallet covers (2) and (3) were used in conjunction with dry ice to produce high carbon dioxide (CO_2) atmospheres.

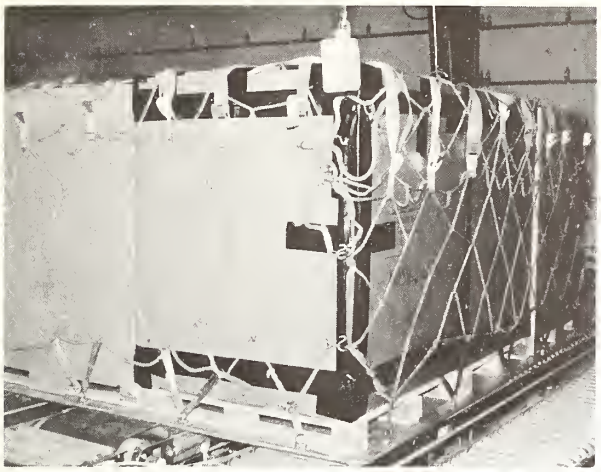

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FIGURE 1.—Strawberries in regular pallet cover (left) and sealed pallet cover (right) assembled on master pallet awaiting loading on plane in San Francisco.

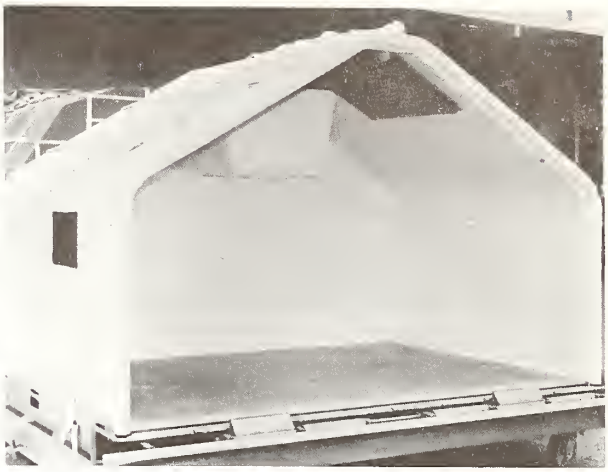

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FIGURE 2.—Nitrogen refrigerated container, showing heat exchangers and gas ejector tube in ceiling.

Dry Ice

Dry ice (about 10 pounds) was wrapped in heavy paper and placed in an empty strawberry flat. An additional empty flat was always set below the one containing dry ice, and paper or fiberboard was used in the latter to help insulate the berries in surrounding flats from the dry ice. The paired flats (with dry ice and insulation) were set in the top two layers of the sealed pallet loads just before shipment.

Refrigerated Container

Shipments to Zurich and London included some strawberry pallets that were loaded in a nitrogen refrigerated container, or "igloo," at the origin airport. The igloo tested had 65 gallons of liquid nitrogen held in an insulated tank. The nitrogen passed from the tank through two heat exchangers in the ceiling of the igloo and was released into the container through a gas ejector tube (fig. 2). This tube served to mix the cold nitrogen gas with air in the igloo and also directed the mixed gases over the heat exchangers to improve refrigeration. Thermostatically operated valves controlled the release of nitrogen into the igloo. The thermostat was set at 36° F. for the Zurich shipment and 40° for the London shipment.

Handling in Transit

During shipment the strawberries were handled by conventional commercial procedures. They were hauled in refrigerated trucks to the airport, where the strawberry pallets were set on airline master pallets. Each master pallet accommodated six strawberry pallets, which were held in place by a cargo net. After the master pallets were made up, they were kept in a freight storage area to await loading on the jet airfreighter (fig. 1).

Berries shipped in the nitrogen refrigerated container were on strawberry pallets, but without fiberboard covers. They were placed in the container at the origin airport. The particular container tested was only large enough to hold four strawberry pallets plus some unpalletized flats of fruit.

Most shipments were transferred to a different plane in New York. The transfer usually involved a simple moving of the entire airline master pallet from one plane to the other (fig. 3), but in one shipment the load on the

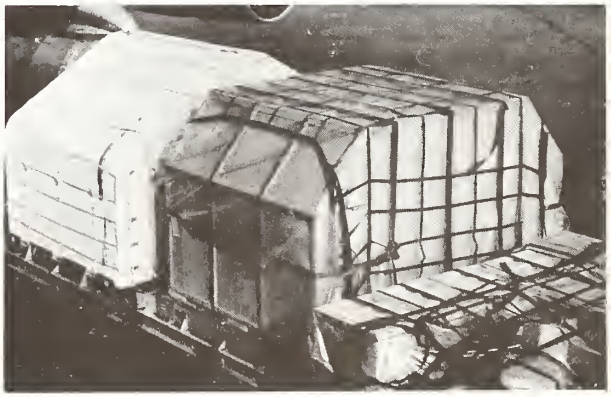

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FIGURE 3.—Nitrogen refrigerated container (left) during freight transfer in air terminal.

master pallet was disassembled and the individual strawberry pallets were moved separately, then reassembled on another master pallet at the connecting airline.

At terminal airports the strawberry pallets were removed from the master pallets. In Frankfurt the berry pallets were opened at the airport and individual flats were distributed in small vans to various buyers in Germany (fig. 4). In Zurich and London the strawberry pallets were hauled by truck to the wholesale market or wholesalers' cold room before they were disassembled.

The commercial handling of the berries beyond the terminal airport was not followed in detail because of diverse methods of marketing in the various cities. However, fruit from the commercial lots was observed in wholesale markets, and test flats of berries were examined in detail after holding under simulated marketing conditions (see section on quality evaluations).

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FIGURE 4.—Strawberries being unloaded from pallets in Frankfurt airport, from which they are distributed in vans.

Temperature Measurement

Transit temperatures were measured at intervals en route with thermocouples and a potentiometer by U.S. Department of Agriculture personnel, who accompanied most of the test shipments. The thermocouples were placed in berries in the top and middle layers of each pallet. When accompanied, the test pallets were always placed in the No. 1 (forward) position on the plane, which made the test equipment accessible and permitted the thermocouple wires and other equipment to pass through the safety net into the vestibule, where readings could be taken. An additional thermocouple was placed outside the pallets to measure ambient temperatures on the plane and at transfer points.

In test pallets that were not accompanied, the temperature readings were taken in New York during the transfer of pallets, at which time the thermocouple junctions on the tops of the pallets were accessible. Personnel of the Department's Market Pathology Laboratory collected data at the New York airport. Readings at destination were taken by a Department man who had accompanied an earlier shipment.

Temperatures of the berries in the refrigerated container were taken with thermocouples that had leads to the outside of the container. Readings could be taken only when the container was off the plane at origin, at transfer points, or at destination (fig. 3).

Gas Sampling

When dry ice was used, a gas sampling tube was inserted into the pallet load for measuring carbon dioxide and oxygen concentrations at intervals in transit. Atmosphere composition was determined with an Orsat-type analyzer. In unaccompanied test pallets an atmosphere analysis was made at the airport before departure, at the New York airport, and on arrival at the destination airport. In accompanied test pallets additional analyses also were made in the plane and at various transfer or stopover points.

Atmospheres in the liquid nitrogen refrigerated container were taken through a tube leading to the outside of the container. Readings were taken at the same time temperatures in the container were determined.

Quality Evaluations

Test flats were removed from the pallets when they were disassembled, and the flats were taken by automobile to a place where they

could be examined shortly after arrival and after being held 1 additional day at room temperature (about 60° F.). The berries were examined individually for decay, softening, bruising, and other defects. Shipments that were unaccompanied were met at the airport by a Department man who had accompanied an earlier shipment to Europe.

Analysis of Data

Data on temperature, atmosphere, decay, and softening were averaged from readings taken on several similar flights. The combined data from the several flights provided a more representative result on which to base conclusions than readings from individual flights. Data on fruit softening were treated statistically by an analysis of variance.

RESULTS

Time in Transit

Strawberries shipped from California to various European markets had an average total transit time of 28.3 hours (fig. 5). Of this total time, about 2.7 hours or 9.2 percent was spent in the truck going to the airport, 13.8 hours or 49.2 percent on the plane, and 11.8 hours or 41.6 percent in airports.

The hours spent in airports were divided into 3.1 at the origin airport, 6.5 at stopovers or transfers, and about 2.2 at destination airports.

Temperatures in Transit

Ambient temperatures. — Ambient temperatures of strawberries exported in the spring and fall varied considerably in individual shipments and in various parts of the transit period (fig. 6). Based on five tests, average ambient temperatures en route were as follows: 44° F. in the truck going to the airport, 67° at the origin airport, 58° on the plane going to New York and at the New York airport, about 60° on the overseas flight, and about 60° at destination airports. Since most of the test shipments passed through New York in the colder part of the day and in the cooler months of the year, there was little or no warmup at that airport.

Temperatures of fruit shipped in pallet covers.—Strawberries precooled to an average temperature of about 37° F. and shipped in either regular fiberboard or coated fiberboard pallet covers had a middle layer temperature of 43° on arrival at the European airports (fig. 6). The rise in middle layer temperatures was very gradual during transit. Top layer temperatures, in contrast, rose very quickly at the origin airport, then more gradually in transit to an average final temperature of 57°.

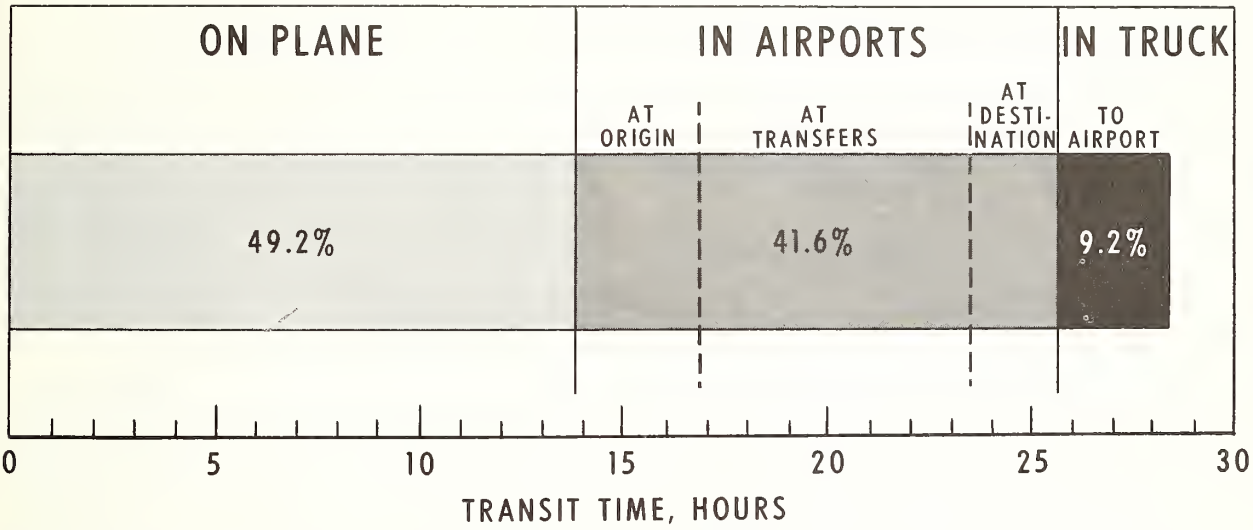

FIGURE 5.—Proportion of transit time for stated phases of shipping California strawberries by air to European markets.

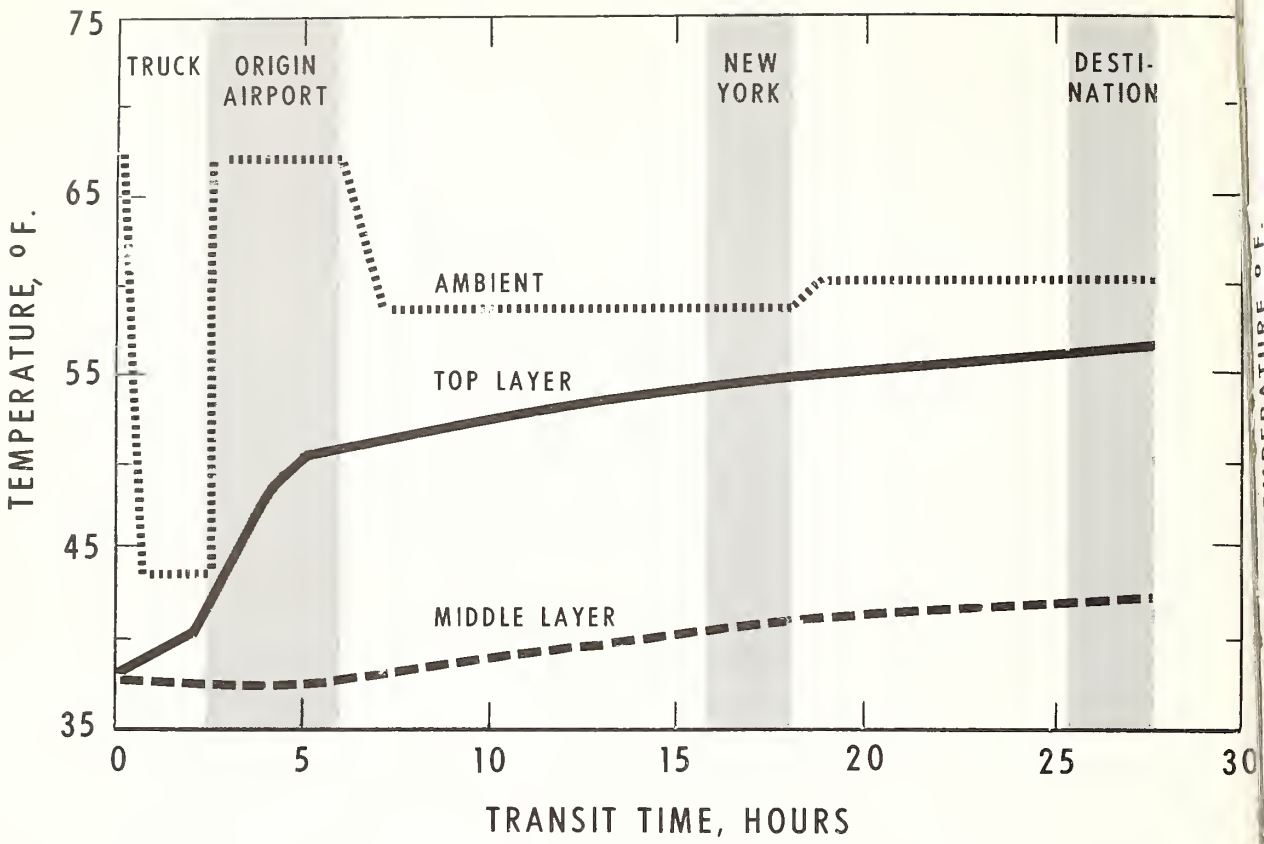

FIGURE 6.—Average temperatures of California strawberries shipped in fiberboard pallet covers to various European markets.

Temperatures of fruit shipped in nitrogen refrigerated container. — Partially precooled fruit shipped from California to Zurich was cooled slightly in the refrigerated truck going to the airport, but showed no appreciable temperature change in a liquid nitrogen refrigerated container while in transit between the origin and destination airports (fig. 7). Fruit temperatures averaged between 45° and 48° F. in the container and ranged from a minimum of 41° to a maximum of 51°.

Thoroughly precooled berries (35° F.) shipped to London showed a small rise in temperature in the truck going to the airport and a further rise while in the nitrogen refrigerated container (fig. 7). Fruit temperatures averaged 39° at the origin airport, 45° at New York, and 43° at London. The minimum temperature in the container was 35° and the maximum 51°. There was about a 6° spread in temperature at destination.

Atmospheres in Transit

Atmosphere modification in sealed pallets (plus dry ice) and in the nitrogen refrigerated container is shown in table 2. Both the coated, taped pallet covers and the covers with polyethylene liners were effective in maintaining CO_2 atmospheres. At New York average CO_2 atmospheres in the sealed pallets ranged from 13 to 27 percent and at destination from 10.5 to 21 percent. Oxygen atmospheres (O_2) in the sealed pallets were reduced only moderately in comparison with normal air.

In the nitrogen refrigerated container, CO_2 levels increased only slightly over those in normal air. However, oxygen levels were greatly reduced by the purging action of the nitrogen refrigerant. The lowest level of O_2 measured was 0.5 percent at Zurich. In this shipment the O_2 level had increased to 11.5 percent in New York, because the nitrogen supply was depleted. The tank was recharged with liquid

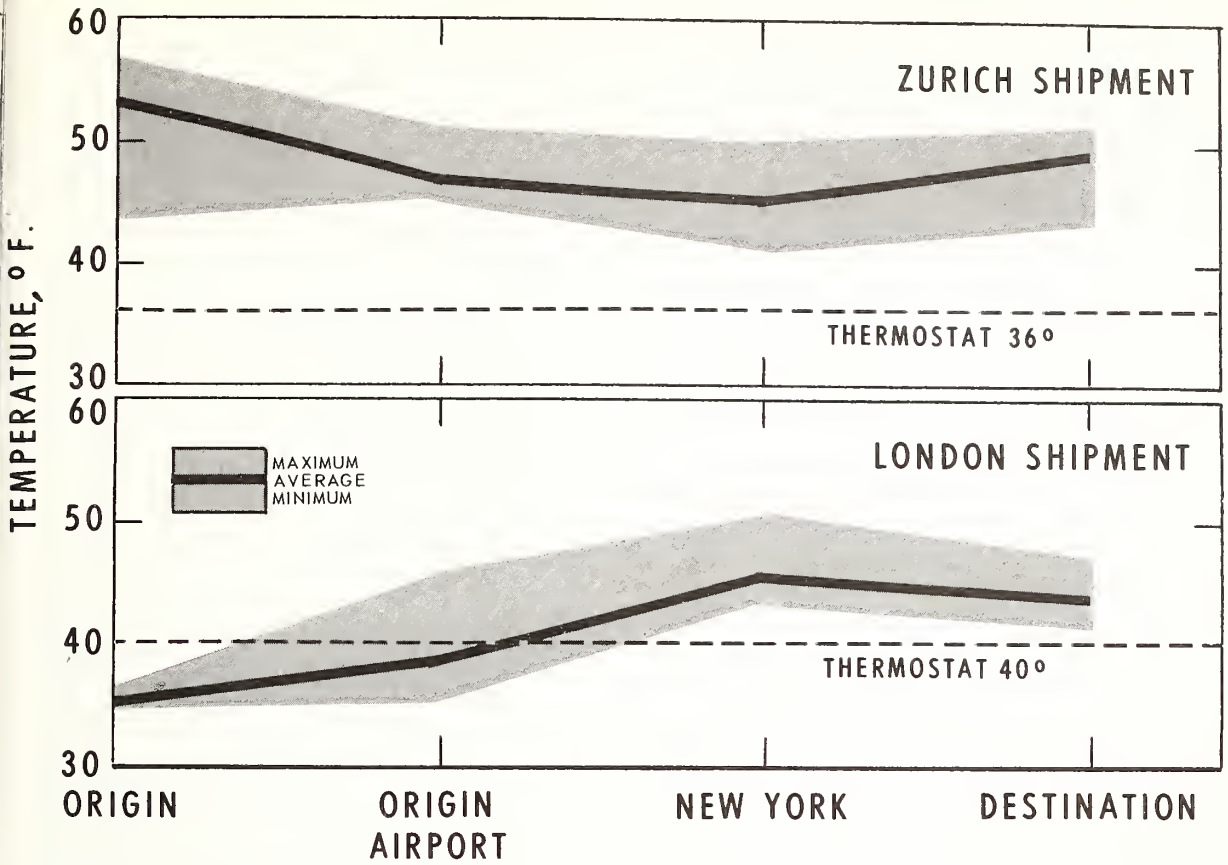

FIGURE 7.—Temperatures of California strawberries shipped in nitrogen refrigerated container to indicated European markets.

TABLE 2.—*Atmosphere modification in strawberry air export tests—spring 1967*

Place	Zurich test				London test				Frankfurt test, sealed pallets [1]	
	Sealed pallets [1]		Nitrogen refrigerated container		Sealed pallets [1]		Nitrogen refrigerated container			
	CO_2	O_2	CO_2	O_2	CO_2	O_2	CO_2	O_2	CO_2	O_2
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Origin airport	23.5	13.0	0.5	2.0	8.0	16.0	--	--	12.0	14.5
New York	27.0	12.0	1.5	11.5	17.0	13.0	0.5	7.5	13.0	12.5
Stopover	--	--	1.0	1.0	--	--	--	--	--	--
Destination	21.0	14.0	0	.5	15.0	13.0	.5	4.5	10.5	15.0

[1] Pallet covers with polyethylene liners or coated with polyethylene and wax with all seams tightly taped.

nitrogen in New York and had a small supply left when the container arrived in Zurich.

In the London shipment the nitrogen container had 7.5 percent O_2 in New York and 4.5 percent on arrival at London.

Berry Quality

Decay in relation to type of pallet cover and position in pallet. — Decay percentages were generally lower in sealed pallets, in which effective concentrations of CO_2 were allowed to build up, than in pallets with regular covers (table 3). This result is consistent with previous tests in the laboratory and in domestic test shipments. Carbon dioxide levels ranged from 15 to 23 percent during most of the time in transit for tests made in the fall of 1966. Lower CO_2 levels (5 to 15 percent) occurred with pallet covers used in the spring of 1966 and no reduction in decay was obtained.

TABLE 3.—*Decay in relation to atmosphere modification in strawberry pallets exported to Europe—fall 1966*

Atmosphere and type of pallet	Decayed berries when examined at destination	
	Shortly after arrival	After 1 additional day when held at about 60° F.
	Percent	*Percent*
Normal (air), regular cover.	3.0	9.5
High CO_2, coated cover or polyethylene liner.	1.4	5.3

Decay was consistently higher in the top layers of pallets than in the middle layers (table 4), a reflection of the higher temperatures in the top layers. In the spring of 1966, about five times as much decay developed in the top as in the middle layer of fruit when it was first examined shortly after arrival. In the fall, decay was much less, but over twice as much decay developed in the top layer by the first examination. The relative differences in decay in relation to position in the pallet were not quite so great when the fruit was again examined 1 day after arrival, but the percentage of decay was still substantially higher in the top than in the middle layer.

TABLE 4.—*Decay in relation to position in strawberry pallets exported to Europe—1966*

Season and position (layer)	Decayed berries when examined at destination	
	Shortly after arrival	After 1 additional day when held at about 60° F.
	Percent	*Percent*
Spring:		
Top	28.1	50.3
Middle	5.7	15.3
Fall:		
Top	3.1	8.8
Middle	1.3	6.0

In the spring of 1967, decay was negligible in all lots. Consequently, the relative effects of atmospheres on decay could not be evaluated in the nitrogen refrigerated container and in the sealed and regular pallet covers.

Berry softening in relation to atmosphere modification in transit.—About a third more berries were soft, overripe, and bruised when shipped in regular pallet covers with normal atmospheres (4.34 percent) than those shipped in coated covers or covers with polyethylene liners with high CO_2 atmospheres (3.15 percent).[2] The softening was accompanied by a darkening of the fruit surface and sunken areas that were moist to the touch. Such fruit was easily bruised when handled.

Strawberries shipped in a nitrogen refrigerated container with a low oxygen atmosphere had over twice as many soft berries (9.35 percent) as fruit shipped in coated pallet covers or covers with polyethylene liners (4.30 percent).[2] Slightly more softening occurred in berries shipped in the nitrogen container than in those shipped in regular covers with a normal atmosphere (7.37 percent).

[2] Difference statistically significant at 5 percent level.

DISCUSSION AND CONCLUSIONS

The average time of 28.3 hours required for exported strawberries to travel from shipping points to terminal airports contrasts with the 17 to 18 hours required for domestic shipments to reach the wholesale market. The proportion of the time spent on the plane and the number of transfers are greater than for domestic shipments. Except for the time spent in the refrigerated truck going to the airport, the berries were exposed to ambient temperatures near 60° F. during most of the time in transit. Obviously the effects of any unfavorable conditions on quality of strawberries are accentuated under export conditions.

Fruit temperatures were undesirably high in the top layers of pallets, but the middle layers averaged only about 6° F. higher at destination than at shipping point. Previous studies on temperature profiles in pallet loads of precooled berries shipped by air from California to markets in the Eastern United States (*7*) indicated that the middle layer temperature at the center of the pallet load closely represented an average for the whole pallet. With a longer transit time, the average temperature for the pallet would probably be slightly higher than that in the center of the middle layer. Most of the berries in the pallet would be in a relatively favorable temperature range, therefore, but several flats in the top layers would be at undesirably high temperatures. Considering the value of California strawberries on arrival in European markets, a serious loss of quality in 6 to 12 flats of berries in each pallet represents a substantial economic loss (table 4).

Berries shipped in the refrigerated container to Zurich had undesirably high temperatures in transit, primarily because they were not properly precooled at shipping point. The container also ran out of liquid nitrogen before reaching New York and some loss of refrigeration resulted. Berries shipped to London in the refrigerated container were well precooled and, for the most part, remained in a favorable temperature range, although some temperature rise occurred and temperatures varied from 6° to 9° F. within the container. Although this variation is less than that in an ordinary palletized load of precooled berries, the average temperature of pallets shipped by the two methods would differ only slightly (figs. 6 and 7).

Atmosphere modification in sealed pallet covers (with dry ice) is characterized by relatively high CO_2 levels and only slightly lowered O_2 levels. In contrast, the atmospheres in a nitrogen refrigerated container had only slightly increased CO_2 levels and greatly lowered O_2 levels. Previous work (*6*) has shown that high CO_2 atmospheres significantly reduce decay, particularly when temperatures are above 40° F. Other research (*4*) has shown that oxygen must be lowered to at least 0.5 percent to reduce decay of strawberries and that lowering it below 0.25 percent causes off-flavors under certain conditions of time and temperature. Controlling oxygen within this very narrow range is difficult, and it is impossible with the present equipment used to refrigerate with liquid nitrogen.

Berry softening was least in sealed pallet covers with high CO_2 atmospheres and greatest in the nitrogen refrigerated container with the low O_2 atmosphere. Softening of the fruit also was greater in regular pallets with a normal atmosphere than in sealed pallets. Two factors are involved in berry softening under these conditions: First, CO_2 retards ripening (*3*) and thus accounts for the difference in softening of berries in sealed pallets and in regular pallets; and secondly, very low oxygen levels contribute to berry softening (*9*) and may account for the larger number of soft berries in the nitrogen refrigerated container.

The use of high CO_2 atmospheres in transit offers the advantage of reducing decay, reducing the number of soft or overripe berries, and improving the overall quality of strawberries, and therefore partially compensates for the lack of refrigeration in transit. Effective levels of CO_2 can be obtained by using dry ice and sealed, coated fiberboard pallet covers or polyethylene liners. Additional work is being done to develop pallet covers that can be tightly sealed with less labor than was required in these tests.

Two tests are insufficient to evaluate the performance of a nitrogen refrigerated container. The idea of providing controlled in-transit temperatures for strawberries is commendable, particularly for export shipments, although the economic feasibility of the practice remains to be determined. The unit tested was designed to maintain temperature, not to cool fruit, and the results of the Zurich shipment demonstrated that transit temperature cannot be lowered when fruit is not adequately precooled. None of the fruit reached the 36° F. setting of the thermostat. In the London shipment, in which the fruit was well precooled, there was a slight rise in temperature, somewhat above the 40° F. thermostat setting. The temperature spread was considerable between the coldest and warmest positions in the load.

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